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Original Research

Enhancing Anger Perception With Transcranial Alternating Current Stimulation Induced Gamma Oscillations

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ABSTRACT

Background: In recent years a variety of neuroimaging studies have highlighted a role of neural oscillations in perception and cognition. However, surprisingly little is known about oscillatory activity underlying facial emotion perception. The limited number of studies that have addressed this question indicate that gamma oscillations are one mechanism underlying this process.
Objective: The present study aimed to further elucidate the role of neural oscillations within the gamma range in facial emotion perception in healthy adults by using transcranial alternating current stimulation (tACS).
Methods: To that effect we carried out three experiments with separate groups of participants using tACS to modulate occipital oscillations while participants completed facial anger and facial identity tasks.
Results: The results of these experiments indicated that modulating occipital gamma with 40 Hz tACS enhances facial anger perception.
Conclusion: This finding implicates an important role of occipital gamma oscillations in facial emotion perception.

Introduction

Recently there has been a great interest in documenting the role of neural oscillations and synchrony in perception and cognition [21,35]. For example, neural activity in the gamma band has been linked to temporal binding and gestalt perception (e.g. Refs. [5,29]). Moreover, various frequencies within the gamma range have been found to have different functional roles in low-level visual processing (e.g. in contrast perception; [18]). Further, disrupted oscillatory activity is often associated with various cognitive and perceptual impairments in a variety of disorders (e.g. Refs. [4,32]).

Despite this, surprisingly little is known about neural oscillatory activity underlying facial emotion perception. Studies exploring this question have indicated that gamma oscillations are one mechanism underlying this process [3,28,30]. For example, in groups with deficits in emotion perception, such as Autism Spectrum Disorders (ASD; [34]), gamma oscillations have been reported to be reduced when perceiving emotion from faces [10,36].

While many of our insights into the role of neural oscillations in perception and cognition are drawn from neuroimaging, recently a number of studies have utilized transcranial alternating current stimulation (tACS) as a tool to probe the functional role of specific oscillations on performance. tACS is a relatively novel non-invasive brain stimulation technique that can be used to modulate cortical activity in a frequency dependent manner [2]. For example, in the visual domain tACS stimulation in the beta band evokes phosphenes in illuminated settings while tACS stimulation in the alpha band evokes phosphenes in the dark [13]. It is also possible to use tACS to modulate cognitive and perceptual performance. For instance [24], demonstrated that tACS induced synchronization in the theta range over fronto-parietal region results in enhanced performance on a visual memory task, and [18] have shown that modulating occipital gamma with tACS can improve contrast perception.

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Author contributions: ABJ and MJB developed the study concept and design. CFPT-Angry was developed by CR. Testing and data collection were performed by ABJ. ABJ performed the data analysis. All authors contributed to the manuscript preparation.

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While previous studies have used other forms of transcranial current stimulation (tCS) to study social perception abilities (e.g. [19,25,31]), to date no study has used tACS to examine the role of cortical oscillations in social perception. The advantage of tACS over other types of tCS (e.g. transcranial direct current stimulation or transcranial random noise stimulation) is that it can not only provide information about brain areas involved in social perception, but also about the role individual frequency bands play in this process [2]. Based on prior findings linking occipital gamma with facial emotion perception, here we conducted two studies using tACS as a tool to examine the extent to which modulating occipital gamma would influence emotion perception abilities of healthy adults. In the light of previous findings it was hypothesized that using tACS to modulate occipital gamma would enhance facial emotion recognition.

Experiment 1: the role of occipital gamma and occipital alpha in anger perception

Experiment 1 used a within participants design in order to examine the degree to which modulating occipital gamma or occipital alpha with tACS would influence facial expression perception. Based on prior work linking occipital gamma to emotion perception abilities (e.g. Refs. [10,36]) we predicted that modulating occipital gamma with tACS would enhance performance relative to occipital alpha stimulation. Since we had no a priori reason to assume that occipital alpha stimulation would differ from sham stimulation, this form of stimulation was chosen as an active control condition in order to examine the extent to which occipital gamma stimulation may influence performance in a frequency specific manner.

Experiment 1: method

Participants

30 healthy adult participants (21 female, 9 male, mean age 25.33 ± 7.04) took part in this experiment. All participants were healthy volunteers, without any known developmental or neurological disorders and no contraindications to tACS. They were naive with respect to the experimental hypothesis. Participants provided written informed consent to take part in the experiment. They were either paid £5 for participating in the experiment or were awarded course credits.

Task

To examine facial expression abilities, the Cambridge Face Perception Angry Expression (CFPT-Angry) was used. In each trial participants were simultaneously presented with a row of six frontal view pictures of a model showing different degrees of anger at 0, 8, 16, 24, 32 and 40% morphed with a neutral expression (Fig. 1A). The stimuli were constructed from male and female images taken from the Radboud Faces Database [20]. The participants' task was to sort these images from the least to most angry by moving pictures with a computer mouse to what they believed was their correct position. This task consisted of ten test trials and two practice trials. Participants were allocated 1 min per trial. Performance on this task was measured using an error score representing total deviations calculated by summing the deviations of each image from its correct location. For instance if the picture was three spaces from its correct position the error score for that trial would be three. Error scores on each trial were summed to determine the total number of errors. We then used this to calculate the percentage of correct responses. Chance performance for CFPT-Angry is 36%.

Stimulation parameters

A battery-driven DC-Plus stimulator (neuroConn) was used. Stimulation was delivered using 5 cm × 7 cm conductive-rubber electrodes enclosed in saline-soaked sponges. The reference electrode was placed over Cz and the stimulating electrode over Oz, according to the international 10–20 system. Two types of stimulation were delivered: gamma (40 Hz) and alpha (10 Hz). The

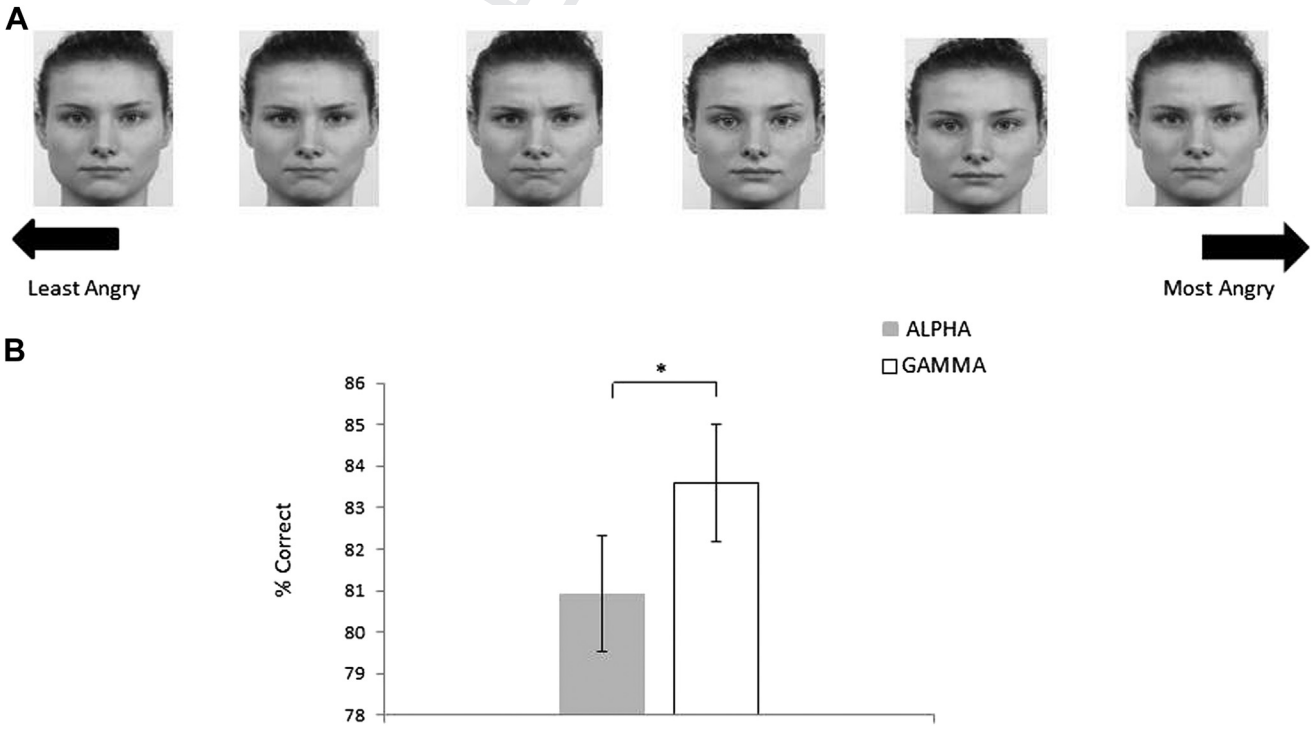

Figure 1. (A) Example of the CFPT-Angry. In this task participants are asked to sort six faces from most angry to least angry. The faces containing varying levels of anger ranging from 0 to 40%. (B) Modulating occipital gamma with tACS significantly improved participants performance on the CFPT-Angry relative to the tACS in the alpha band. * = $P < .05$.